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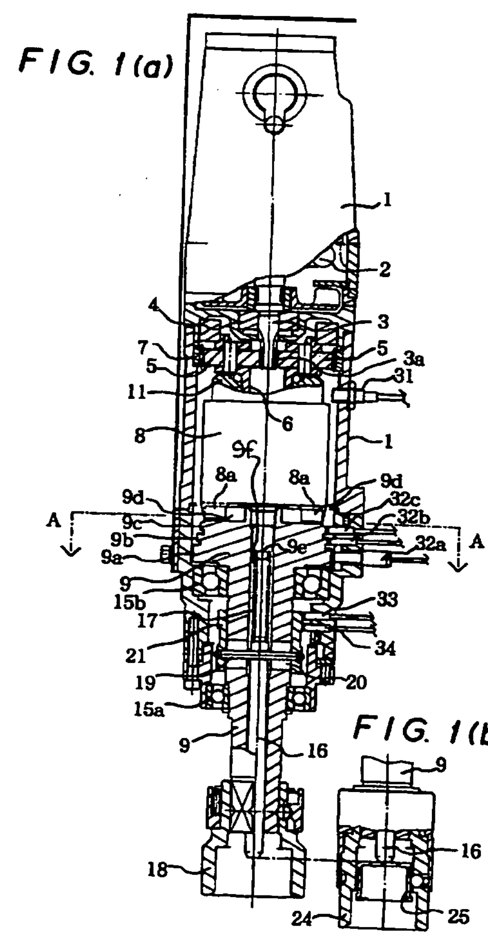
(54) **Bolt tightening.**

(57) The present invention provides an impact wrench and a bolt-tightening method wherein a spring force is applied, through the circumference of a spindle (6) coupled with the output shaft of an electric motor, in the forward direction to a hammer (8) which is capable of forward and rearward movement and of rotational motion following said spindle (6), with said hammer (8) and impact shaft (9) being brought in coaxial mesh alignment by leaving a gap between them in the direction of rotation so that when a bolt to be tightened is inserted into a socket fixed to an end of said impact shaft (9) to permit the bolt to be tightened, the mesh contact with said impact shaft (9) is released as a result of said hammer (8) being lifted up in the rearward direction against the reaction force due to the tightening of said bolt, and as said hammer (8) is again brought into mesh contact with the impact shaft (9) under the spring force applied in the forward direction so that an impact force is generated with respect to the direction of rotation of said impact shaft (9), an impact sensor (31) detecting the release of said hammer (8) from said impact shaft (9) and an angle sensor (32) measuring the angle of rotation of said impact shaft (9) are provided, so as to measure the torque of said impact shaft (9) by measuring the amount by which the angle of rotation of said impact shaft (9) advances each time said impact force is generated and to measure the amount by which the angle of rotation of said impact shaft (9) advances from the time at which said measured torque has reached the previously set snug torque value, so that the power supply to said electric motor is disconnected when the amount of advancement of the rotational angle has reached the pre-defined value of the preset angle of rotation to stop the rotation of said impact shaft (9) through the braking circuit.

FIG. 1



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This invention refers to railway construction, and particularly concerns an impact wrench for the tightening of bolts for railway track fixed by means of a plate-shaped tightening spring, and further relates to a method for tightening bolts using an impact wrench designed so that bolt tightening is achieved with the required spring compression force by measuring the angle of rotation of the impact shaft from the time of the preset snug torque's being generated.

Track rails have hitherto been secured by tightening bolts on to wooden, metal and concrete crossties or sleepers by means of a plate-shaped tightening spring to hold down the rail. In tightening these bolts, a significant level of skill is necessary as the application of the required tightening torque for tightening the bolts with the conventional impact wrench up to the prescribed spring compression force has had to be left to the judgement and skill of the operator.

The familiar impact wrench is designed so that a hammer is coaxially meshed with the impact shaft to rotate the bolt-tightening socket, with an axial force being applied to said hammer by means of a spring in the direction of the impact shaft. When bolts are tightened, the hammer rotates under the drive force of the electric motor and said impact shaft rotates while the hammer and the impact shaft are in mesh. When the bolt-tightening reaction force overcomes the spring force applied to the hammer, however, the hammer will be lifted and separated from the impact shaft to permit its free rotation. Immediately after this, the hammer is again subjected to the spring's compression force to come into mesh with the impact shaft. As this mesh contact is obtained, a knocking force is applied to the impact shaft while the hammer is rotating so as to tighten the bolts.

The impact wrench thus requires a specific timing at which the measurement of the angle of rotation is commenced in order to ensure that the bolts are tightened by the fixed angle of rotation previously set by the rotational angle method.

To achieve automatic control of the conventional type of impact wrench, the inventor has achieved further progress with the invention of an impact wrench using the rotating angle method in such a manner that the angle of rotation of the impact wrench is measured and the electric motor is stopped when the predetermined angle of rotation has been reached. (Japanese Utility Model Registration Application No. 4430/1992)

The impact wrench based on the rotational angle method disclosed in Japanese Utility Model Registration Application No. 4430/1992, however, had been designed so that the timing for the release of the hammer from the impact shaft was specified in terms of the time at which the snug torque is generated so that the motor was stopped when the angle of rotation measured thereafter reached the predetermined amount of bolt-tightening.

In practical bolt-tightening operations, however, it sometimes happens that the bottom of the rail is lifted up out of contact with the crosstie (floating crosstie) before the bolt is tightened. The problem in such cases is that the possibility that the motor might be stopped before the correct bolt-tightening condition was achieved since for the tightening of bolts by the above rotational angle method, the compression force for bringing the rail into contact with the PC crosstie was used as the reaction force acting in the upward direction so that the measurement of the angle of rotation would commence before the correct snug torque was detected.

In view of these earlier problems, the inventor has adopted a bolt-tightening method which is a combination of a torque method with the rotational angle method for automatic impact wrench control. (Japanese Patent Application No. 19650/1993)

In this bolt-tightening method, the angle of rotation of the impact shaft and the torque are measured from the time at which the snug torque is achieved so as to ensure that the electric motor will stop when both the impact shaft's angle of rotation and the torque have reached the prescribed values.

This type of bolt-tightening method is thus capable of resolving and overcoming the problem associated with the rotational angle method and the problem inherent in the torque method, that is, the problem of the electric motor's stopping before the tightening of the bolt is completed in the floating crosstie condition and the problem of variations in the tightening force applied to the bolt due to the influence of varying conditions of the mating screw thread surfaces.

With this combined bolt-tightening method, however, the time at which the snug torque is generated was specified as the time at which the hammer is released from the impact shaft and impact is generated. As a result, a difference occurred in the time of completion of bolt-tightening by the rotational angle method and that by the torque method, thereby giving rise to the problem of errors arising in either of these methods.

The purpose of the present invention, resulting from the above considerations, is to provide a bolt-tightening method using an impact wrench in such a manner as to resolve the conventional problems associated with defining the time at which snug torque is achieved, and ensure that the correct bolt-tightening conditions are automatically achieved regardless of the environmental conditions in which bolt-tightening takes place.

To overcome the above problems, the present invention provides an impact wrench and a bolt-tightening method wherein a spring force is applied, through the circumference of a spindle coupled with the output shaft of an electric motor, in the forward direction to a hammer which is capable of forward and

rearward movement and of rotational motion following said spindle, with said hammer and impact shaft being brought in coaxial mesh alignment by leaving a gap between them in the direction of rotation so that when a bolt to be tightened is inserted into a socket fixed to an end of said impact shaft to permit the bolt to be tightened, the mesh contact with said impact shaft is released as a result of said hammer being lifted up in the rearward direction against the reaction force due to the tightening of said bolt, and as said hammer is again brought into mesh contact with the impact shaft under the spring force applied in the forward direction so that an impact force is generated with respect to the direction of rotation of said impact shaft, an impact sensor detecting the release of said hammer from said impact shaft and an angle sensor measuring the angle of rotation of said impact shaft are provided, so as to measure the torque of said impact shaft by measuring the amount by which the angle of rotation of said impact shaft advances each time said impact force is generated and to measure the amount by which the angle of rotation of said impact shaft advances from the time at which said measured torque has reached the previously set snug torque value, so that the power supply to said electric motor is disconnected when the amount of advancement of the rotational angle has reached the pre-defined value of the preset angle of rotation to stop the rotation of said impact shaft through the braking circuit.

The method and apparatus of the invention will now be described in detail with reference to the accompanying drawings in which:

Figure 1a is a cross-sectional drawing of an impact wrench according to this invention;
Figure 1b is a partial cross-sectional drawing of a nut socket capable of being installed to replace the bolt socket of the impact wrench shown in Figure 1a;
Figures 2a and 2b are partial cross-sectional drawings of the impact-generating part of the impact wrench according to this invention;
Figure 3a is a view taken in the direction of line A-A of the angle sensor according to this invention;
Figure 3b is a waveform diagram for the output voltage signals from the angle sensor of Figure 3a;
Figures 4a to 4c are sectional drawings illustrating the shape sensor and socket sensor for the bolt socket of the impact wrench;
Figures 5a to 5c are sectional drawings illustrating the shape sensor and socket sensor for the nut socket of the impact wrench;
Figures 6a to 6c are explanatory drawings illustrating the bolt-slackening action using the impact wrench;
Figure 7 shows a bolt-tightening machine with two built-in impact wrenches of the present invention mounted on the left and right, respectively;
Figure 8a is a circuit diagram of the impact wrench according to this invention;
Figure 8b is a circuit diagram of the brake circuit of the impact wrench according to this invention.
Figure 9 is a chart illustrating the bolt-tightening operation of the impact wrench according to this invention;
Figure 10 is a chart illustrating the bolt-slackening operation of the impact wrench according to this invention; and
Figure 11 shows the relationship between the tightening torque and the rotational angle for the floating crosstie or sleeper associated with the impact wrench according to this invention.

This invention is characterised in that the timing for the generation of the snug torque is not, as has been the case in the past, taken as the time of the start of impact generation, varying as this does as a result of different factors but that the tightening reaction force of each bolt being tightened is detected after an impact has been generated by measuring the angle of rotation through which the bolt advances with each impact, that is, by measuring the amount of advance of the rotational angle associated with any one impact, in such a manner that the time at which the amount of angular advancement has reached a preset snug torque (the predetermined snug torque value) is taken as the origin for beginning to measure the angle of rotation of the impact shaft, with the electric motor stopping when this rotational angle has reached a predetermined value (the set rotational angle value).

In this bolt-tightening method, the predetermined snug torque value is variable so that it can be set in accordance with the bolt-tightening environment.

Figure 11 is used here to explain the operation using the impact wrench shown in Figure 1 for tightening floating crosstie bolts.

Figure 11 shows that the torque $\underline{a}$ for generating the impact is smaller than the torque needed for lifting the floating crosstie (lift-up torque $\underline{b}$). The predetermined snug torque value $\underline{c}$ is set to a value larger than this lift-up torque $\underline{b}$.

When the bolt socket 18 mounted on to the impact shaft 9 is seated onto a bolt head, and the electric motor 2 is started, the bolt head will correctly mesh with the socket 18 when the shape sensor 34 has switched on (d) so that a fit is detected on the plate spring.

When the hammer 8 lifts from the impact shaft 9 and the impact sensor 31 switches ON (e), an impact is generated which impact is taken as the starting point (origin) for measuring, with angle sensor 32, the amount of advance of the rotational angle with each impact. Since these impacts are of constant energy,

i.e. each blow delivered to the impact shaft has the same energy as the last and the next blows, the angle through which the impact shaft moves at each impact is a measure of the torque applied by resistance to rotation of the fastener (bolt or nut) being tightened, and is thus a measure of the torque applied to the fastener by the wrench. As each impact is generated as a result of the impact created as the plate spring's compression reaction force, it follows that this is the time at which the plate spring begins to compress.

In the case of floating crossties, the crosstie will still remain separated from the rail even when such an impact is generated so that the lift-up torque b will remain practically unchanged until the crosstie makes contact with the rail, and this occurs irrespective of the advance of the rotational angle. When the crosstie does make contact with the rail, the plate spring used for holding down the rail will begin to be compressed so that the torque will increase.

At the time (f) at which the angle of advance of the impact shaft 9 with each impact as measured with angle sensor 32 has reached the angle associated with the predetermined snug torque value, this is taken as the starting point for measurement of the total rotational angle required for tightening the bolt to the required final torque. Starting from this point, the rotational angle of the impact shaft 9 is measured with angle sensor 32, and the rotation of the impact shaft 9 will be competed when this value has reached the predetermined rotational angle value.

The following practical examples of the present invention are used to explain this invention, making reference to the attached drawings.

The impact wrench shown in Figure 1a has an elecric motor 2 installed in casing 1, and the circumference of its output shaft 3 is supported in a bearing 4. At the front end of the output shaft 3 of the electric motor 2, there is a gear 3a on its circumference, and the two idling gears 5 and 5 meshing with said gear 3a are supported in symmetrical positions at the rear end of the spindle 6. The circumferential gear portions of the two idling gears 5 and 5 are in mesh with the internal gear portion of a ring gear 7 which is mounted in casing 1.

This arrangement is designed so that when the output shaft 3 of the electric motor 2 rotates, the idling gears 5 and 5 on both sides will rotate, being guided by ring gear 7, with the result that spindle 6 will rotate at a speed slower than that of shaft 3.

As shown in Figure 2, the interior of the hammer 8 has a cup-shaped spring cap 11 inserted at the rear end of spindle 6 while the hammer 8 is a freely sliding fit on the circumference of the front part of spindle 6. The rear portion of the hammer 8 forms an outer cylinder 8c and the interior of this outer cylinder 8c is a free-sliding fit on the circumference of the spring cap 11. Between the spring cap 11 and the hammer 8, a spring 12 is provided in a coaxial arrangement with spindle 6 in such a manner that said hammer 8 is forced in the forward direction (towards the socket 18) with respect to spring cap 11.

Furthermore, the circumference of said spindle 6 is provided with inclined grooves 10 of limited length arranged in symmetrical positions, with balls 13 provided in each of the inclined grooves 10 so that their circumference is in sliding contact with the hollow part 8b of the front portion of hammer 8. As a result, said hammer 8 is forced forward under the spring force of spring 12 while the balls 13 are capable of reciprocal movement within the range in which they can move along inclined grooves 10.

Furthermore, the front end of said hammer 8 takes the form of two forwardly-protruding teeth 8a and 8a arranged symmetrically with respect to the shaft. The impact shaft 9 provided at the front end of said hammer 8 is fixed and supported at the front and rear on bearings 15a and 15b seated in casing 1 in such a manner as to permit free rotation, while the two protruding teeth 9d provided at the rear of impact shaft 9 are arranged symmetrically with respect to the shaft. Each protruding tooth 8a of said hammer 8 meshes with a respective protruding tooth 9d of impact shaft 9, with a gap left between them in the direction of rotation.

Moreover, as shown in Figure 1a, the front end of impact shaft 9 is fitted with a detachable bolt socket 18. This bolt socket 18 is interchangeable with the nut socket 24 shown in Figure 1b.

When the motor 2 rotates with the bolt socket 18 seated on a bolt head, the hammer 8 will, as a result of this arrangement, be pushed forward, as shown in Figure 2a, as it follows the guide of bore 13 in the initial phase in which the spring force of spring 12 is greater than the torque of impact shaft 9, at which time the protruding teeth 8a of hammer 8 will rotate while meshing with the protruding teeth 9d of impact shaft 9.

As the bolt-tightening force gradually increases and the reaction force pushing the impact shaft 9 up in the rearward direction becomes greater than the spring force of spring 12, the hammer 8 will be pushed, as shown in Figure 2b in the rearward direction so that the protruding teeth 8a of hammer 8 come out of their engagement with the protruding teeth 9d of impact shaft 9. The hammer 8 is thus temporarily released from the load of impact shaft 9 but will move forward, guided by the balls 13 in a helical movement, immediately afterwards under the action of the force of spring 12.

As a result, the protruding teeth 8a of hammer 8 and the protruding teeth 9d of impact shaft 9 will collide with each other in the next mating position (the condition of Figure 2a), thereby causing an impact force to be generated on impact shaft 9.

The following examples explain the various detectors provided in this system.

1) Impact sensor 31 (refer to Figures 1 and 2) The metal detecting impact sensor 31 for casing 1 is installed in the proximal position at the rear end on the circumference of the outer cylinder 8c of hammer 8. This impact sensor 31 has a conventional proximity switch arranged so as to detect the presence of metal by the relative spacing or distance from it, in such a manner that an OFF signal is generated when the hammer 8 mates with the impact shaft 9 (the condition of Figure 2a) and that an ON signal is generated when the hammer 8 is pushed rearward and separated from the impact shaft 9 (condition of Figure 2b).

Since the impact action of hammer 8 on the impact shaft 9 takes place immediately after the hammer 8 has separated from impact shaft 9, it will be possible for the impact sensor 31 to detect the occurrence of an impact, as the time when this impact sensor 31 generates an ON signal.

2) Angle sensor (refer to Figures 2 and 3) A first, second and third displacement track 9a, 9b and 9c, respectively, are successively created by displacing the respective outer diameters along the circumference at the rear end of the metal impact shaft 9. The shaping of these displacement tracks 9a, 9b, 9c is discussed in more detail below. In addition, a displacement sensor 32a and the proximity switches 32b and 32c are arranged opposite the first, second, and third displacement tracks 9a, 9b and 9c, respectively, in the casing 1, so as to constitute the angle sensor 32 for detecting the angle of rotation of the impact shaft 9 through a combination of these first, second, and third displacement tracks 9a, 9b and 9c and the displacement sensor 32a and proximity switches 32b and 32c.

The displacement sensor 32a consists of an overvoltage-type displacement sensor and is capable of measuring the outer-diameter displacement of the first displacement track by determining the distance of the sensor 32a from the outer circumference of the first displacement track 9a and reflecting a variation in this distance as a change in the output voltage. The proximity switches 32b and 32c both function on the same principle as that of the displacement sensor 32a, with the difference, however, that the proximity switches generate ON/OFF signals according to their respective distances from the second and third displacement tracks 9b and 9c.

As shown in Figure 3a, the circumference of the first displacement track 9a has an elliptical shape such that the diameter B1-B2 is somewhat larger than the diameter C1-C2 which intersects the former at right angles, so that said first displacement track 9a has a displacement contour with a periodicity of 180°. As a result, the output voltage measured by displacement sensor 32a when the impact shaft 9 is rotating, exhibits a peak-and-valley output waveform with a periodicity of 180° as shown in Figure 3b.

As shown in Figure 3a, the circumference of the second displacement track 9b, however, is shaped in such a manner that the arc of its circumference extending from B1 to B2 in a clockwise direction as seen in Figure 3a has a large diameter than the arc extending from B2 to B1 in the clockwise direction. Thus a change from the greater to the smaller diameter, and vice versa, takes place at a periodicity of 180°. The 180° detection signals obtained from the first proximity switch 32b measuring the circumference of the second displacement track 9b have a linear output waveform, with the straight line passing through '0' form 0° to 180° and through '1' from 180° to 360°, as shown in Figure 3b.

Furthermore, as shown in Figure 3a, the circumference of the third displacement track 9c is shaped to have portions of two discrete diameters, the smaller diameter portions extending from B1 to C1 in the clockwise direction and from B2 to C2 in the clockwise direction, while the larger diameter portions extend from C1 to B2 in the clockwise direction and from C2 to B1 in the clockwise direction, so that a change from the major to the minor diameter or vice versa takes place at a periodicity of 90°. The 90° detection signals obtained from the second proximity switch 32c measuring the circumference of the third displacement track 9c have a linear output waveform, with the straight line passing through '0' from 0° to 90°, through '1' from 90° to 180°, through '0' from 180° to 270°, and through '1' from 270° to 360°, as shown in Figure 3b.

Over a full 360°, the peak-and-valley waveform of the first displacement track 9a with a periodicity of 180° exhibits four identical output voltage values occurring every 90°. The combination of the second and third displacement tracks 9b and 9c, however, shows different combinations every 90° over a full 360° so that it is possible to determine the location to which the output value of the first displacement track 9a corresponds over the full 360° on the basis of the combination of the second and third displacement tracks 9b and 9c.

When, for example, the first displacement track 9a shows the intermediate value of the peak-and-valley waveform in Figure 3b, the angle of rotation corresponding to this intermediate value may be 45°, 135°, 225° or 315°. Yet, when the 180° detection signal obtained from the second displacement track 9b is '1' and the 90° detection signal obtained from the third displacement track 9c is '0', it follows from this combination that the output value can only be in the range from 180° to 270° so that it may be concluded that the shaft position is 225° if the output from sensor 32a on the first displacement track 9a is at its midpoint, and the outputs of sensors 32b and 32c are 1 and 0 respectively.

Moreover, when the angle of rotation of the first displacement track 9a exceeds 360°, it is possible to determine the absolute value of the angle of rotation

by adding 360° to the angle obtained from the combination of the second and third displacement tracks 9b and 9c appearing for and from the second time.

It is also possible to detect the torque of the impact shaft 9 with said angle sensor 32. When one impact is generated on impact shaft 9, it is possible to calculate the torque of impact shaft 9 by measuring, with angle sensor 32, the amount of advance of the angle of rotation of impact shaft 9 during the period between two successive ON signals generated by impact sensor 31, making use of the fact that the amount of advance of the impact shaft 9 is inversely proportional to the applied bolt-tightening force.

3) Socket sensor 33 and shape sensor 34 (refer to Figures 1 and 4)

The centre of the impact shaft 9 has a through-hole 9f, and the sensor rod 16 is a sliding fit in said through-hole 9f. The rear-end of sensor rod 16 mates with protruding part 9e on the shaft of spindle 9 via a spring 17, so that force is applied to sensor rod 16 in the forward direction. The front end of the sensor rod 16 protrudes into bolt socket 18 from the end of the impact shaft 9. On impact shaft 9, a pair of longitudinal slots 20 is provided so that the pin 19 inserted in sensor rod 16 extends radially through the slots 20 while, at the same time, the two ends of pin 19 are fastened in a sensor case 21. The sensor case 21 is free to slide axially along the circumference of the impact shaft 9.

As a result, the sensor rod 16 can move in the axial (forward and rearward) direction only by the length dimension of said slots 20, and the sensor case 21 following the movement of said sensor rod 16 is caused to slide in the forward and rearward directions on the circumference of the impact shaft 9.

The sensor case 21 is preferably made of a synthetic resin material and a metallic sensor ring 22 is inserted at the rear on to the circumference of sensor case 21. Installed in the vicinity of the side of this sensor ring 22 is the socket sensor 33 on the rear end, and the shape sensor 34 on the front end, with respect to casing 1. Said socket sensor 33 and shape sensor 34 are both metal detectors capable of detecting the presence of the metallic sensor ring 22 so as to detect the forward and rearward position of the sensor rod 16 according to whether or not the sensor ring 22 is detected.

Thus, as shown in Figure 4a, when no bolt head 36a is in the socket 18, the sensor rod 16 is forced forward until the pin 19 makes contact with the lowermost end position of slots 20, while the front end of sensor rod 16 protrudes into socket 18. In this condition, the socket sensor 33 is removed from its mating position with respect to sensor ring 22, and though it is in the OFF condition, the shape sensor 34 will make mating contact and be in the ON position.

As shown in Figure 4b, when the bolt head 36a is fully inserted into the socket 18, the front end of sensor rod 16 will contact said bolt head 36a and the pin 19 will be pushed, against the action of the spring force of spring 17, in the rearward direction until it reaches a position in which it makes contact with the uppermost part of the slots 20. When, in this condition, the depth of socket 18 is larger than the height of bolt head 36a, a gap g will be created between the metal washer 37 and the underside of bolt head 36a. In this condition, socket sensor 33 makes contact with sensor ring 22 and is in the ON state, whereas the shape sensor 34 is removed from its contact position and goes to the OFF state.

Furthermore, when socket 18 is rotated, the bolt 36 will drop inside the socket 18, as shown in Figure 4c and the underside of bolt head 36a will make contact with metal washer 37 so that the gap g will disappear. In this condition, the sensor ring 22 will also drop as the sensor rod 16 descends, so that both the socket sensor 33 and the shape sensor 34 will make contact with said sensor ring 22 and thus go to the ON state, thereby making it possible to detect that the bolt head 36a is correctly seated on metal washer 37 above the tightening spring 38.

In this manner, it is possible to detect whether the bolt head 36a is in the normal engagement condition inside socket 18 by way of detecting that the shape sensor 34 is in the ON state after the socket sensor 33 has acquired the ON state.

In the above arrangement, the bolt socket 18 provided at the front end of the impact shaft 9 can be replaced by the nut socket 24 as shown in Figure 1b. As shown in Figure 5, this is useful for tightening a nut 39a on to a stud bolt 39.

If the bolt socket 18 is used with a nut 39a in mesh with a stud bolt 39, the sensor rod 16 will not be capable of detecting any change in the tightening of nut 39a unless its contact position with stud bolt 39 changes. To permit detection by means of said sensor rod 16, the nut socket 24 is formed by insertion of an inverted cup-shaped nut case 25 in the socket arranged so that its base makes contact with sensor rod 16.

As shown in Figure 5b, this type of nut socket 24 permits free extension of the stud bolt 39 in the interior of nut case 25 when the upper end of nut 39a has contacted the lower circumference of nut case 25. As a result, it is possible, as shown in Figures 5a to 5c using the same action as that explained above for the bolt socket 18, to detect by means of socket sensor 33 and shape sensor 34 that the nut 39a has been tightened, on to a stud bolt 39.

4) Bolt Extraction Height Sensor 35 (refer to Figures 6 and 7)

Figures 6 and 7 show a system with a built-in array of two of the above impact wrenches 45. The trolley frame 42 is equipped with wheels 41 and 41 at the front and rear so that it can be positioned on a track rail 40. The trolley frame 42 is equipped with freely oscillating slide rails 43 and 43 independently posi-

tioned on either side of the rail 40 on which the trolley frame 42 moves. Each of these slide rails 43 and 43 is provided at the top with a wind-up type plate spring 44 an 44 for weight balancing. Guide plates 43a and 43a projecting from the sides of each of the impact wrenches 45 and 45 are slidably inserted in slide rails 43 and 43, and the lower ends of said plate springs 44 and 44 are fastened on to these guide plates 43a and 43a, respectively.

By this means, each of the two impact wrenches 45 and 45 will maintain their floating balance independently suspended on plate springs 44 and 44, so that they can be easily moved up and down by operating the handle 47. It is also possible to alter their front-rear and left-right positions with respect to the bolt 36 to be tightened.

In addition, the impact wrenches 45 and 45 are laterally equipped with a metal detector type bolt extraction height sensor 35, and a vertically movable metal plate 46 is laterally mounted on the slide rails 43 and 43.

The grip of said handle 47 is equipped with an operator switch 48 for clockwise rotation and an operator switch 49 for counter-clockwise rotation, positioned to be operated by the thumbs of the user. The top part of the impact wrench has a controller 50 with an Auto/Manual select switch 51, a rotation angle setting knob 52 and a torque setting knob 53 (see Figure 8).

When the bolt 36 of the rail tightening device is slackened to extract it completely or slacken it only a little, the bolt may come out totally or its height of extraction may not be aligned, seeing that it is not possible to control the extraction height with the manual switch because of the coarse screw pitch of bolt 36.

As a result, provision is made to permit the automatic adjustment of the bolt's extraction height by using, in the above construction, a bolt extraction height sensor 35 and the brake circuit of motor 2.

Thus, the metal plate 46 along slide rail 43 can be adjusted by moving it up or down in such a manner as to previously select the height of the metal plate 46 in accordance with the desired bolt extraction height so that when the bolt extraction height is to be set to a small amount (as shown in h1 of Figure 6b), this metal plate 46 is located in a lower position, and, conversely, when the bolt extraction height is to be set to a large amount (as in h2 of Figure 6c) this metal plate 46 is located in an upper position.

In this manner, the bolt extraction height sensor 35 will be in the OFF condition without detecting the metal plate 46 at the start of the bolt slackening process shown in Figure 6a. As shown in Figures 6b or 6c, however, when the tightened bolt 36 is pushed upwards under the slackening action on tightened bolt 36, the bolt extraction height sensor 35 will go to the ON state when it detects the metal plate 46 in accordance with the desired bolt extraction height and the power supply to motor 2 will be interrupted. The rotation of said motor 2 is then stopped through the brake circuit described below so that the desired bolt extraction height can be achieved automatically.

The following explanations refer to the above impact wrench and sensor circuit layouts as shown in Figure 8a.

Apart from the Auto/Manual select switch 51 and the operator switches 48 and 49 for clockwise and counter-clockwise rotation, the controller 50 also features a rotation angle setting knob 52 and a torque setting knob 53 as well as the above sensors, that is, the impact sensor 31, the angle sensor 32 (the first, second and third displacement sensors 32a and the proximity switches 32b and 32c), the socket sensor 33, the shape sensor 34, and the bolt extraction height sensor 35 all of which are designed to provide input to the controller 50.

The output from controller 50 is applied to the electric motor 2 through the clockwise rotation relay 54, the counter-clockwise rotation relay 55 and the brake relay 56, while the solid state relay 57, receiving the commands from controller 50, is connected with the clockwise rotation relay 54, the counter-clockwise rotation relay 55 and the brake relay 56 so that the intermittent ON/OFF action (inching) of solid state relay 57 is controlled by the ON state of the relays 54, 55, and 56.

As shown in Figure 8b, the clockwise and counter-clockwise rotation circuits and the brake circuit for the electric motor 2 are designed so that the brake relay (b) for the single-phase electric motor 2 with a series-wound collector is operated in the ON condition of the clockwise rotation relay (R) or the counter-clockwise rotation relay (F).

The operating procedure for the bolt tightening process using the impact wrench described above will be explained by referring to the charts of Figures 9 and 10.

As shown in Figure 9, the total rotational angle setting has been preset with the rotation angle setting knob 52, and the snug torque setting has been made using torque setting knob 53.

The head 36a of the bolt 36 to be tightened is now inserted into the socket 18, and the auto switch 51 is turned to ON so that when the clockwise rotation operator switch 48 (hereinafter called the clockwise rotation switch) is turned ON, the clockwise rotation relay 54 is in the ON state.

When the socket 18 is properly engaged on bolt head 36a, the socket sensor 33 goes to ON and the operation sequence moves to the next stage. If, however, the bolt head 36a is not positively engaged in socket 18, the socket sensor 33 will switch to OFF and the solid state relay 57 will control the electric motor 2 in such a manner as to cause repeated start/stop operation (inching) consisting of 0.1 second rotation and 1.0 second stop, with respect to the socket 18. When the socket 18 is eventually correctly engaged

on bolt head 36a, the socket sensor 33 will go to ON.

The next step is to delay rotation by 0.2 seconds using a timer. This means that after the socket 18 has been correctly engaged on the head of bolt 36, there will be a pause of 0.2 seconds until the head of said bolt 36 is completely home in the interior of socket 18.

Following this, the solid state relay 57 goes to ON and rotation is started under the action of motor 2. In this condition, the shape sensor 34 will detect that the head of said bolt 36 is seated on the upper surface of tightening spring 38.

However, the impact sensor 31 will detect that an impact has occurred on impact shaft 9 by detecting the floating condition of hammer 8. From this moment, the angle sensor 32 will measure the angle by which the impact shaft 9 advances each time an impact occurs, and the total angle of rotation of the impact shaft will be measured starting from the time at which the predetermined snug torque value is reached, i.e.from the time at which the angular advance caused by one impact becomes less than a preset limit.

At the time at which the total angular advance of the impact shaft 9 has reached the previously set rotational angle value, the solid state relay 57 will go to OFF and the brake relay 56 will be active.

In this condition, the clockwise rotation switch 48 is timed to remain inactive for 10 seconds although it is in the ON condition so as to prevent its repeat action which could occur as this clockwise rotation switch 48 remains in the ON state.

After rotation of the motor 2 has been stopped under the action of said brake relay 56, the rotational angle measuring value will then be reset when the clockwise rotation switch 54 is stopped.

As shown in Figure 9, the system is designed so that data processing takes place as shown in the Figure when the clockwise rotation switch 48 is in the OFF state. This is achieved through control status data processing for controller 50 and makes it possible to record the tightened state for each and all bolts using, for example, a conventional integrated circuit card.

When bolts are slackened, the metal plate 46 for the bolt extraction height sensor 35 is previously set to a height corresponding to the desired bolt extraction height.

When the socket 18 is not inserted onto the head of the bolt 36 to be tightened and the AUTO switch 51 is in the ON state and the counter-clockwise limit switch (hereinafter called reverse switch) 49 is then switched ON, the counter-clockwise rotation relay 55 will go to ON.

The detection operation of socket sensor 33 in the next stage will be to detect whether or not the socket 18 has been correctly located on the head of bolt 36 in the case of bolt extraction. This is similar to the case shown in Figure 9.

After the socket 18 has been correctly located on the head of bolt 36, the bolt head 36a is allowed to reach its position fully home in the socket 18 by delaying rotation for 0.2 seconds using a timer so that when the bolt extraction height sensor 35 is in the OFF state, solid state relay 57 goes to ON, and conversely, when the bolt extraction height sensor 35 is in the ON state, solid state relay 57 goes to OFF, resulting in the brake relay 56 being active. In this condition, a 10 second timer is operated as above so that when the reverse switch 54 is interrupted after rotation of motor 2 has been stopped, the counter-clockwise rotation relay goes to OFF.

As explained above, the bolt-tightening method using the impact wrench according to this invention is devised so that the tightening reaction force is detected for each bolt actually being tightened by measuring the amount of advance of the angle of rotation associated with any one impact after impact has been generated while the snug torque has been generated, and the time at which this amount of advance of the rotational angle has reached the preset snug torque (snug torque setting) is taken as the starting point for the commencement of measurement of the angle of rotation of the impact shaft, and the electric motor is stopped at the time at which this preset rotational angle has reached the predetermined amount of advance of the rotational angle (preset rotational angle advance).

As a result, the snug torque setting can be varied in this bolt-tightening method so that it is possible to make the settings in accordance with, and to suit, the bolt-tightening environment without using the impact generating period which may vary according to various factors as the snug bolt setting, as has been the case in the conventional bolt tightening methods consisting of rotational angle and torque methods.

Moreover, the angle sensor is a contact-free sensing device with respect to any of the objects measured so that it is not influenced by the thrust force of the impact shaft and thus permits measurement results of high accuracy.

In accordance with the above invention, it is thus possible to achieve automatic bolt-tightening operation under the specified bolt-tightening force without relying on the sense or skill of the operator so that even an inexperienced operator can perform correct bolt-tightening operations without giving rise to variations in the bolt-tightening force.

Claims

1. An impact wrench comprising a motor, a spindle (6) coupled with the output shaft of the motor, a hammer (8) which is capable of forward and rearward movement and of rotational motion following said spindle (6), and a socket (18, 24) fixed to

an end of said impact shaft (9) to engage a fastener (36, 39a) to be tightened, wherein the hammer (8) is resiliently urged in the forward direction into coaxial mesh alignment with the impact shaft (9) and cam surfaces (8, 10, 13) on the hammer (8) and the spindle (6) urge the hammer (8) away from the impact shaft (9) when the torque exerted by the spindle (6) on the hammer (8) exceeds a preset value, a gap being left between the hammer (8) and the impact shaft (9) in the direction of rotation so that when the mesh contact between the hammer (8) and the impact shaft (9) is released as a result of said hammer (8) moving against the resilient force, said hammer (8) is again brought into mesh contact with the impact shaft (9) under the spring force applied in the forward direction so that an impact force is generated with respect to the direction of rotation of said impact shaft (9), characterised in that the impact wrench further includes an impact sensor (31) detecting the release of said hammer (8) from said impact shaft (9), and an angle sensor (32) measuring the angular rotation of said impact shaft (9), so as to measure the torque exerted by said impact shaft (9) by measuring the angle through which the impact shaft (9) advances each time said impact force is generated, the angle sensor (32) serving also to measure the total angle through which the impact shaft (9) advances from the time at which the measured torque reaches a previously set snug torque value, the power supply to said electric motor (2) being disconnected when the total angle has reached a pre-defined value to stop the rotation of said impact shaft (9).

2. An impact wrench according to claim 1, characterised in that the spindle (6) is provided with inclined grooves (10), and balls (13) are positioned in each of the inclined grooves (10) in sliding contact with axial grooves (8b) in the hammer (8), so that when the torque exerted by the spindle (6) on the hammer (8) exceeds a predetermined value the balls (13) move along the grooves (10) and lift the hammer (8) away from the impact shaft (9).

3. An impact wrench according to claim 1 or claim 2, characterised in that the impact sensor (31) is a proximity switch arranged adjacent the end of the hammer (8) remote from the impact shaft (9), and generates an OFF signal when the hammer (8) mates with the impact shaft (9), and an ON signal when the hammer (8) is separated from the impact shaft (9).

4. An impact wrench according to claim 1 , claim 2 or claim 3, characterised in that the angle sensor (32) comprises a first, a second and third displacement track (9a, 9b and 9c), respectively, of varying outer diameters extending round the impact shaft (9), the first displacement track (9a) having a major diameter (B1-B2) and a minor diameter (C1-C2) which intersects the major diameter (B1-B2) at right angles, the second displacement track (9b) having half of its circumference formed by an arc (B1 to B2) of a larger diameter and half of its circumference formed by an arc (B2 to B1) of a smaller diameter, and the third displacement track (9c) is formed by four quadrant arcs of alternate larger and smaller diameters, (B1 to C1, B2 to C2, C1 to B2, and C2 to B1), each displacement track (9a, 9b, 9c), respectively, having a detector (32a, 32b, 32c) sensitive to the diameter of the track at the sensor location.

5. A method of tightening a fastener using an impact wrench wherein a series of rotational impacts are delivered to an impact shaft (9) by a drive means consisting of an electric motor (2), a spindle (6), and an axially reciprocating hammer (8) mounted on the spindle (6), characterised by comprising the steps of:

a) measuring the torque applied to the impact shaft (9) by measuring the angle through which the impact shaft (9) advances each time an impact is generated;

b) determining the instant when the angle measured in step a) reaches a preset limit value;

c) measuring the total angle of rotation of the impact shaft (9) from the instant determined in step b); and

d) disconnecting the drive to the spindle (6) when the total angle measured in step c) has reached a pre-defined value.

FIG. 1

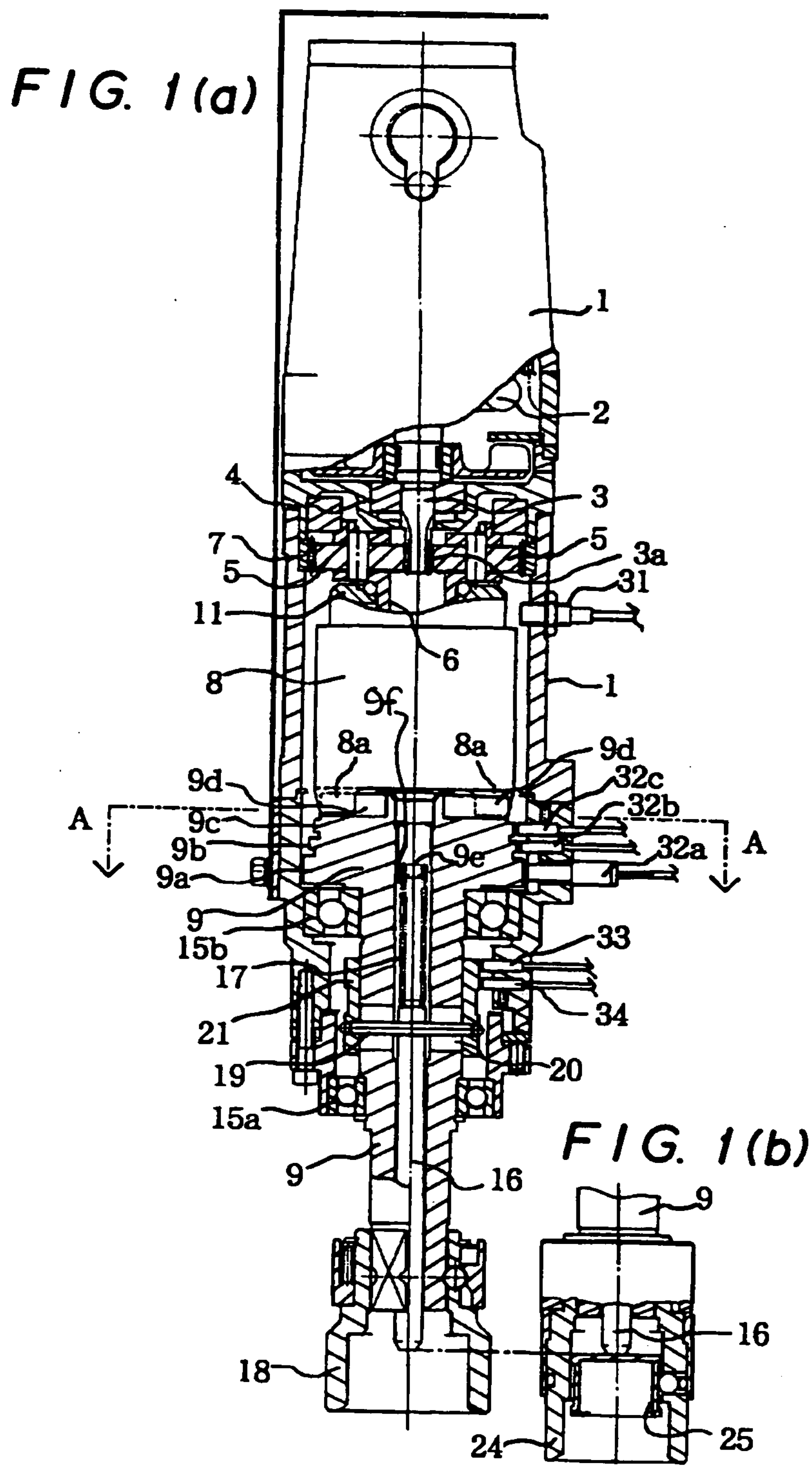
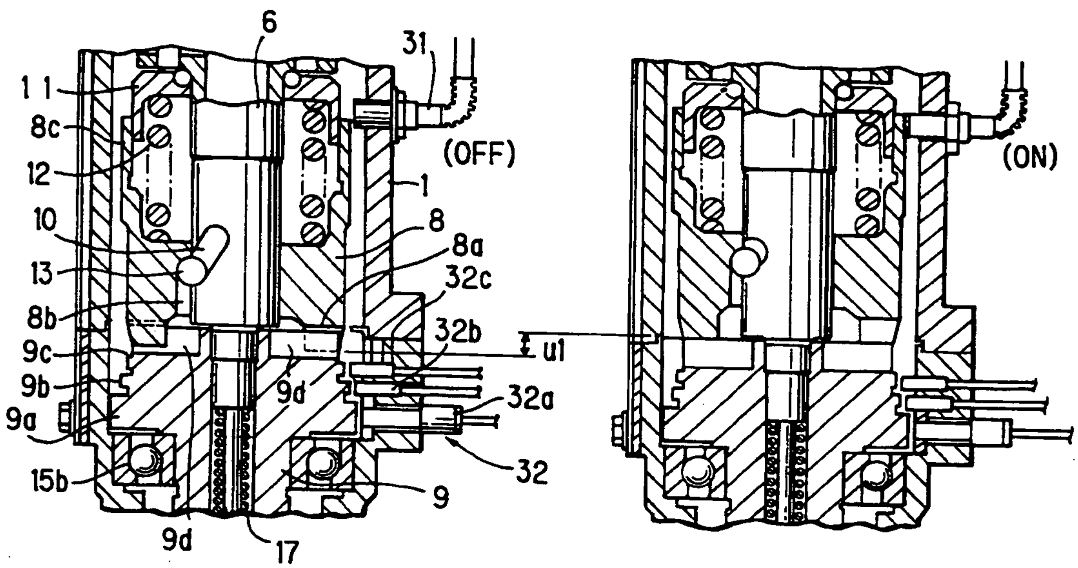
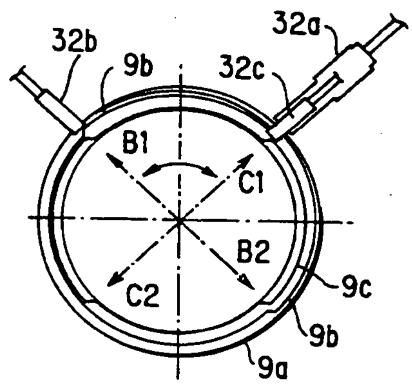


FIG. 1(a)
FIG. 1(b)
1
2
3
3a
4
5
6
7
8
8a
9
9a
9b
9c
9d
9e
9f
11
15a
15b
16
17
18
19
20
21
24
25
31
32a
32b
32c
33
34
A

F I G. 2(a) F I G. 2(b)



F I G. 3(a)



F I G. 3(b)

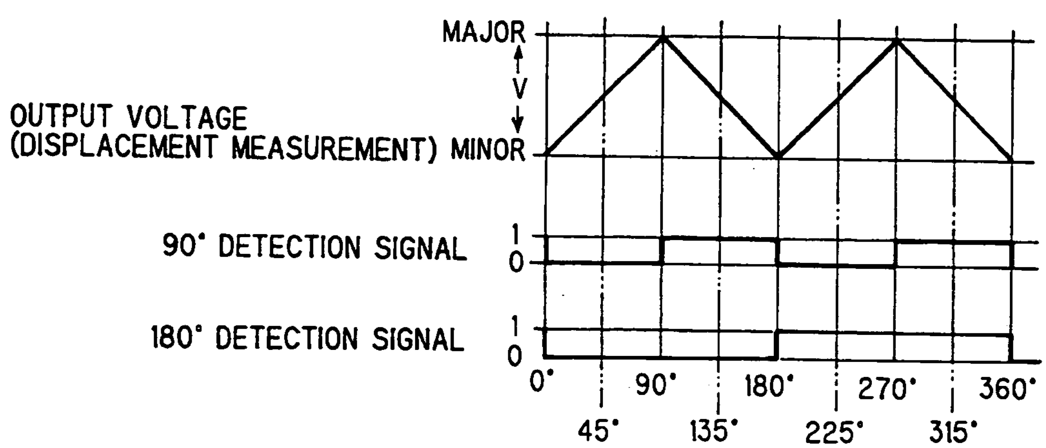


FIG. 4

FIG. 4(a) FIG. 4(b) FIG. 4(c)

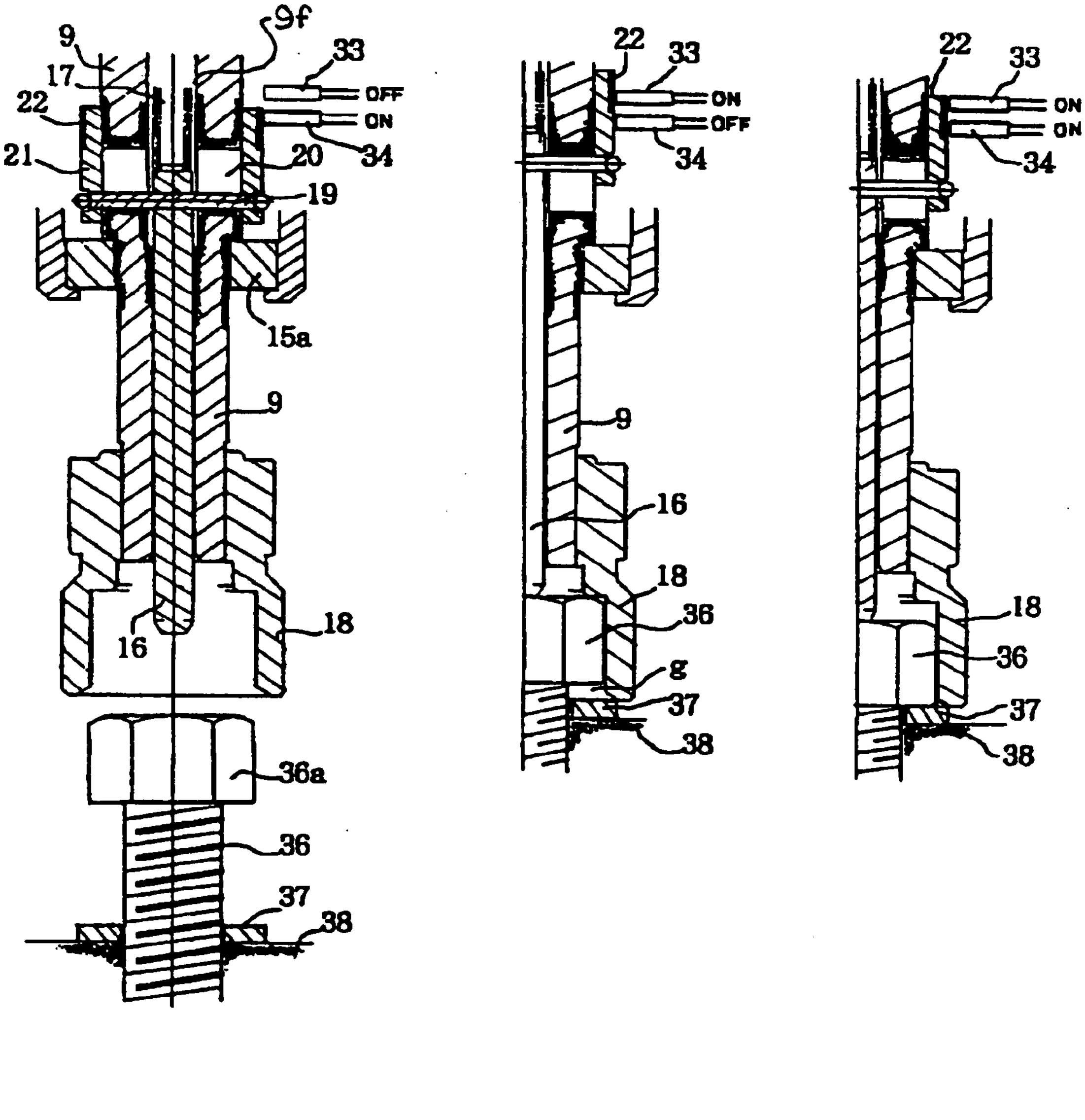


FIG. 5

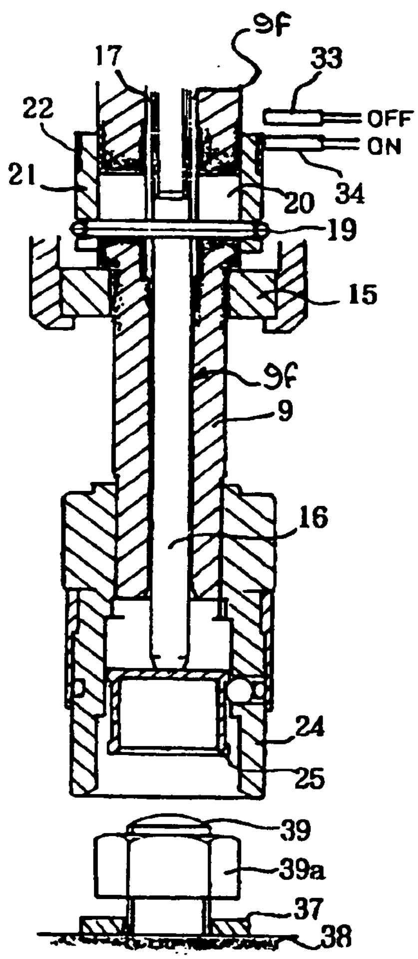


FIG. 5(a)

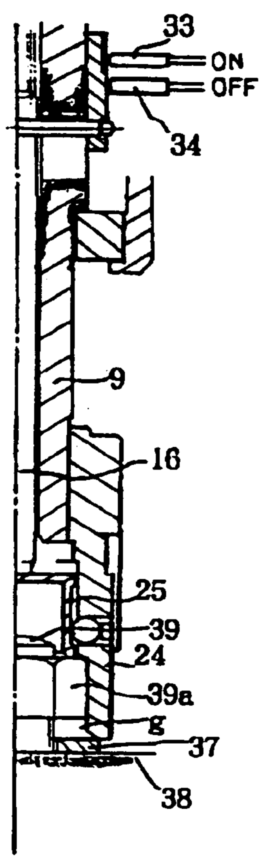


FIG. 5(b)

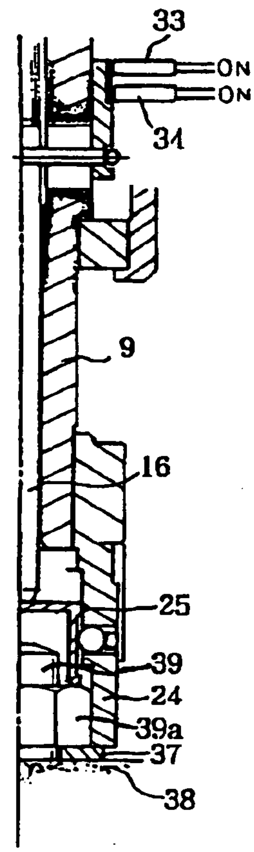


FIG. 5(c)

FIG. 6

FIG. 6(a) FIG. 6(b) FIG. 6(c)

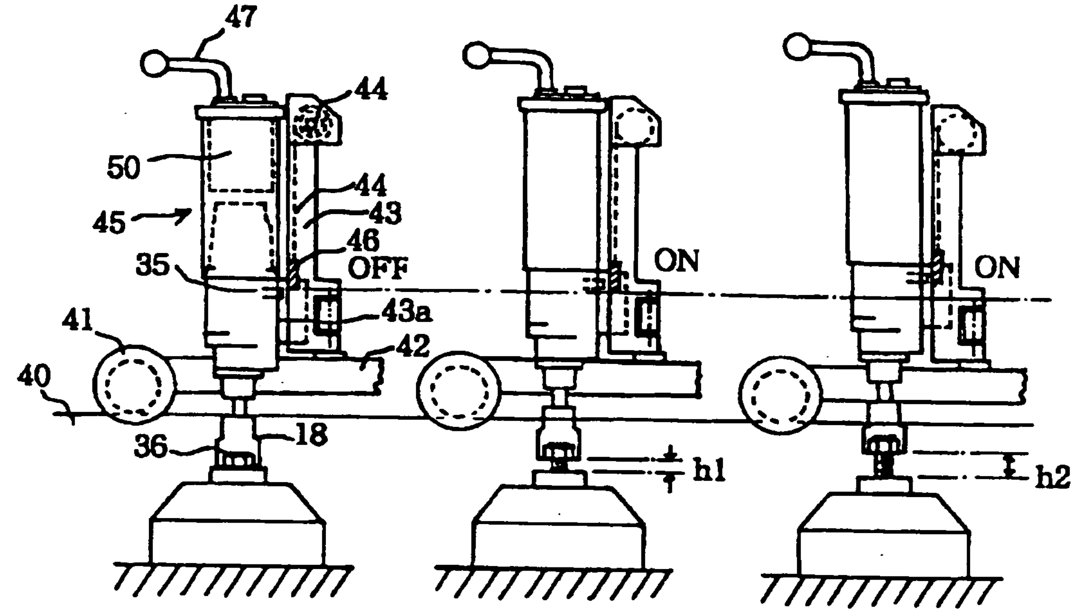


FIG. 7

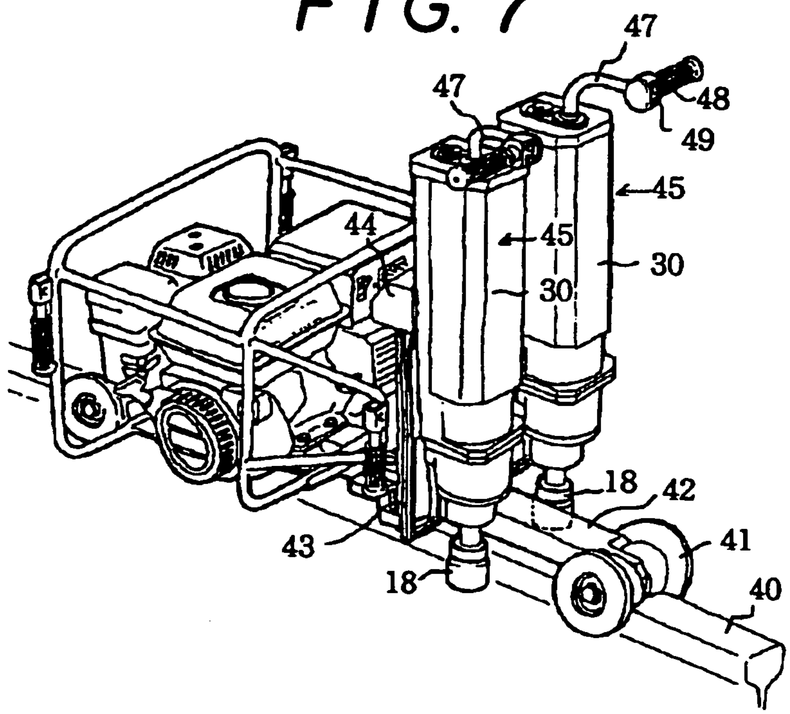


FIG. 8

FIG. 8 (a)

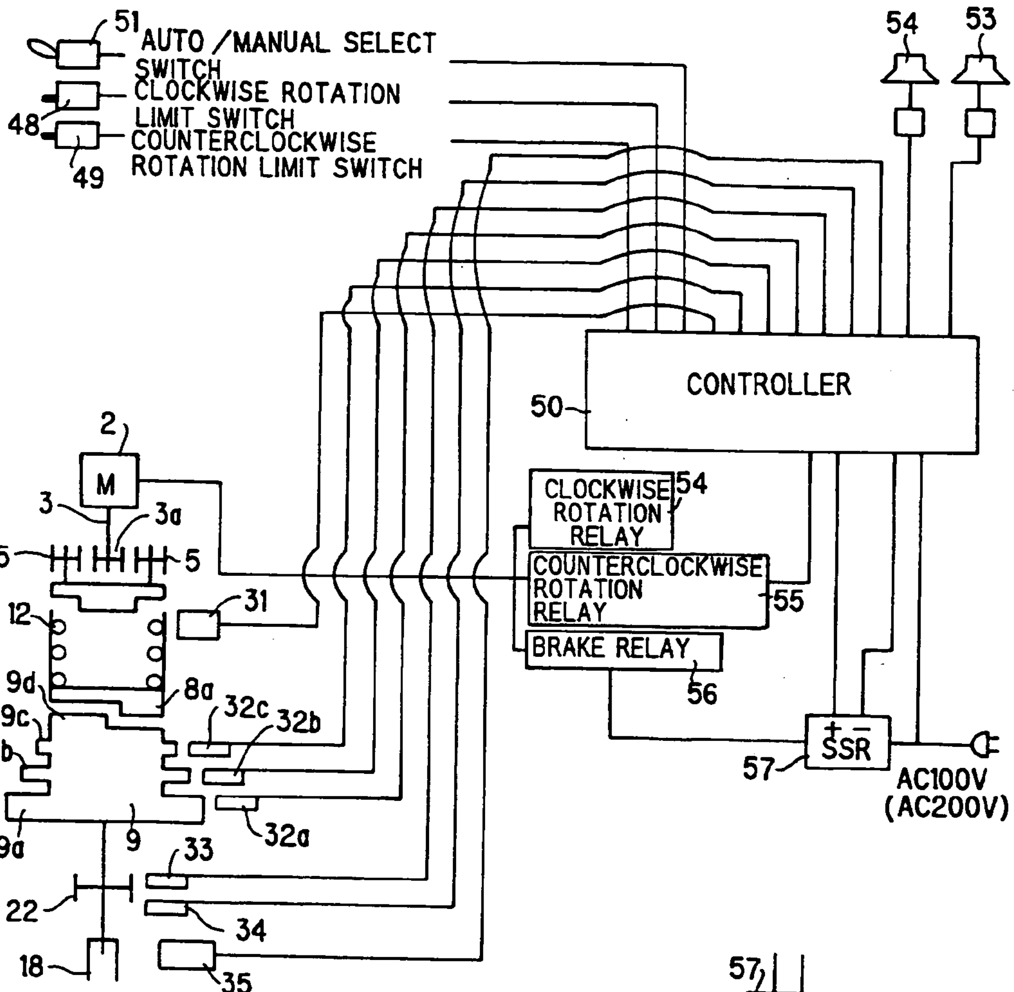
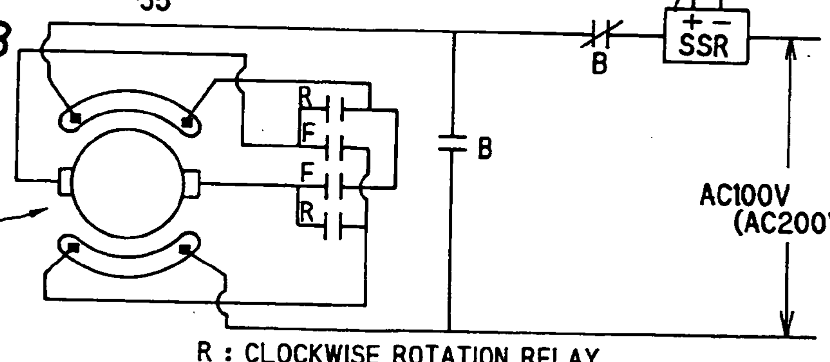
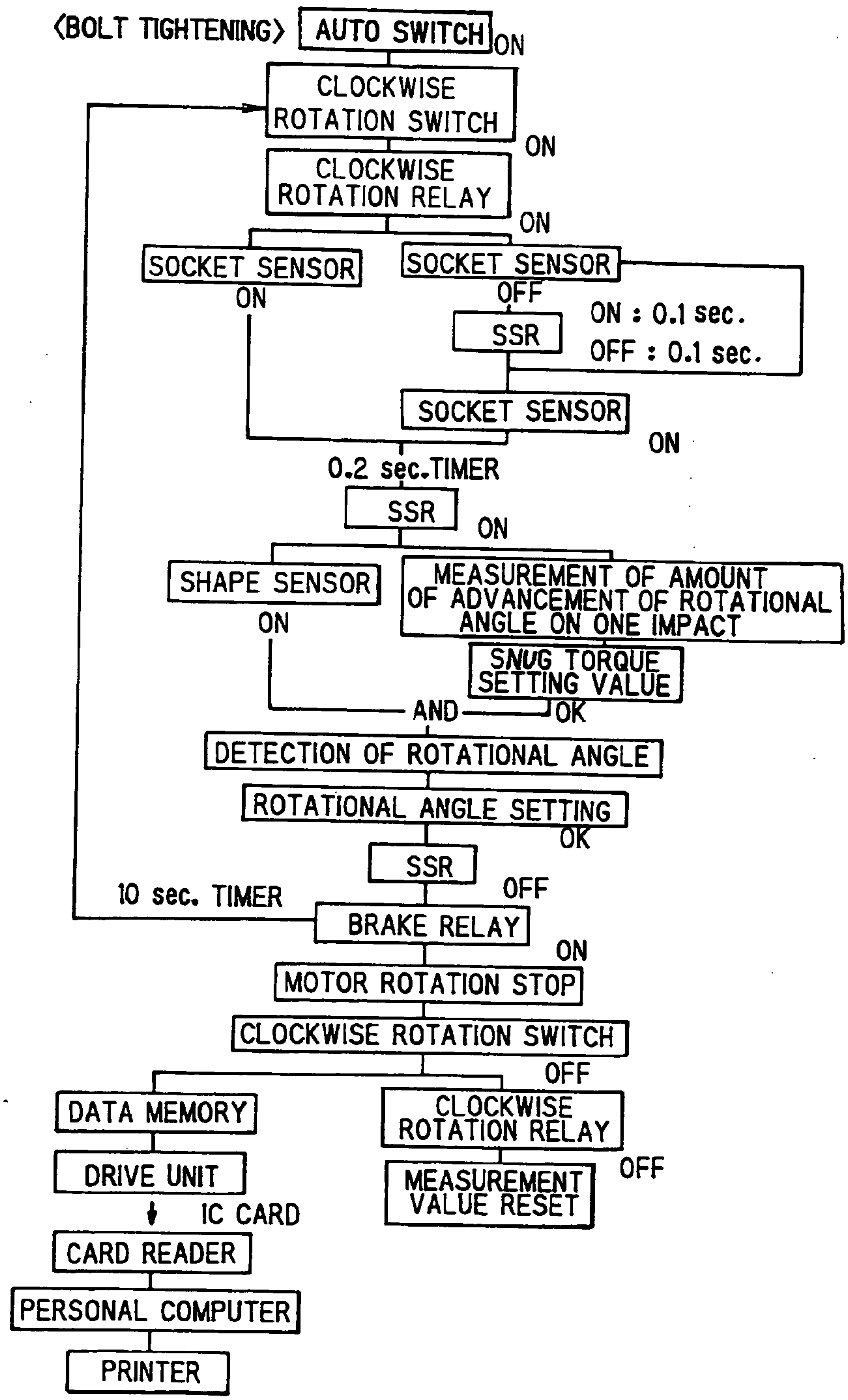


FIG. 8 (b)



R : CLOCKWISE ROTATION RELAY
F : COUNTERCLOCKWISE ROTATION RELAY
B : BRAKE RELAY

FIG. 9



<BOLT TIGHTENING>
AUTO SWITCH
ON
CLOCKWISE ROTATION SWITCH
ON
CLOCKWISE ROTATION RELAY
ON
SOCKET SENSOR
ON
SOCKET SENSOR
OFF
SSR
ON : 0.1 sec.
OFF : 0.1 sec.
SOCKET SENSOR
ON
0.2 sec.TIMER
SSR
ON
SHAPE SENSOR
ON
MEASUREMENT OF AMOUNT OF ADVANCEMENT OF ROTATIONAL ANGLE ON ONE IMPACT
SNUG TORQUE SETTING VALUE
AND
OK
DETECTION OF ROTATIONAL ANGLE
ROTATIONAL ANGLE SETTING
OK
SSR
10 sec. TIMER
OFF
BRAKE RELAY
ON
MOTOR ROTATION STOP
CLOCKWISE ROTATION SWITCH
OFF
DATA MEMORY
DRIVE UNIT
IC CARD
CARD READER
PERSONAL COMPUTER
PRINTER
CLOCKWISE ROTATION RELAY
OFF
MEASUREMENT VALUE RESET

FIG. 10

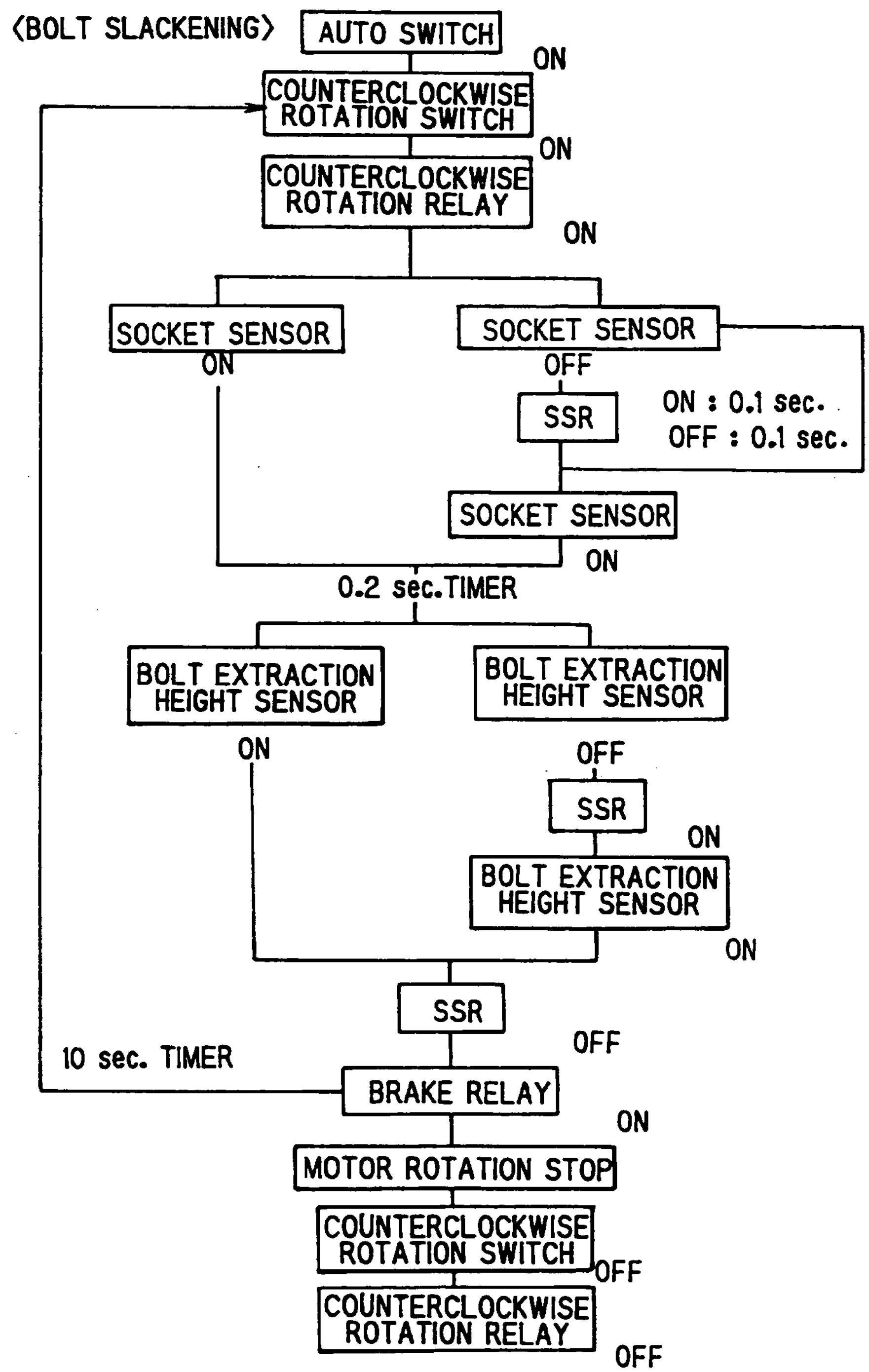
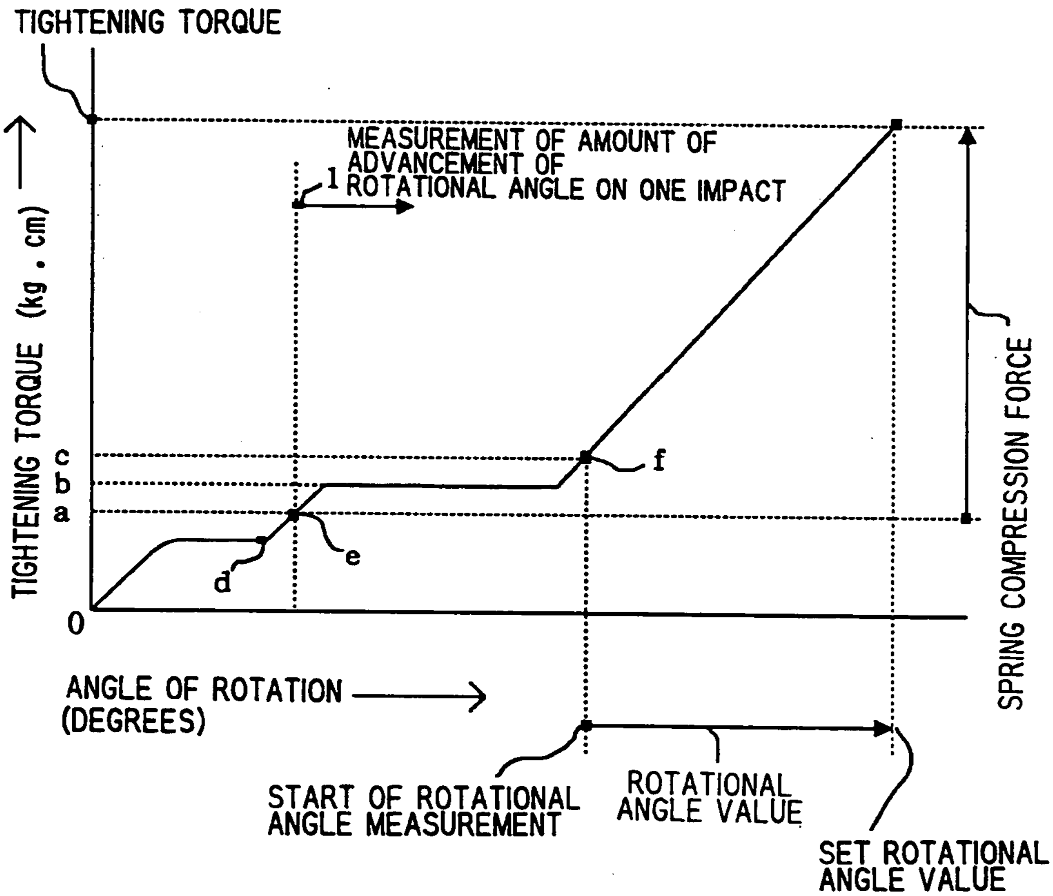

⟨BOLT SLACKENING⟩
AUTO SWITCH
ON
COUNTERCLOCKWISE ROTATION SWITCH
ON
COUNTERCLOCKWISE ROTATION RELAY
ON
SOCKET SENSOR
ON
SOCKET SENSOR
OFF
SSR
ON : 0.1 sec.
OFF : 0.1 sec.
SOCKET SENSOR
ON
0.2 sec.TIMER
BOLT EXTRACTION HEIGHT SENSOR
ON
BOLT EXTRACTION HEIGHT SENSOR
OFF
SSR
ON
BOLT EXTRACTION HEIGHT SENSOR
ON
SSR
OFF
10 sec. TIMER
BRAKE RELAY
ON
MOTOR ROTATION STOP
COUNTERCLOCKWISE ROTATION SWITCH
OFF
COUNTERCLOCKWISE ROTATION RELAY
OFF

FIG. 11



TIGHTENING TORQUE
TIGHTENING TORQUE (kg . cm)
MEASUREMENT OF AMOUNT OF ADVANCEMENT OF ROTATIONAL ANGLE ON ONE IMPACT
1
c
b
a
d
e
f
0
SPRING COMPRESSION FORCE
ANGLE OF ROTATION (DEGREES)
START OF ROTATIONAL ANGLE MEASUREMENT
ROTATIONAL ANGLE VALUE
SET ROTATIONAL ANGLE VALUE

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 2792

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	US-A-2 808 916 (JOHNSON) * column 5, line 27 - line 53; figures 1-3 *	1,2,5	B25B23/14 B25B21/02
A	FR-A-2 452 997 (SPS TECHNOLOGIES) * page 4, line 12 - line 17 * * page 9, line 37 - page 10, line 22 * * page 26, line 24 - page 27, line 9; figures 1,5,6,8,9 *	1,5	
A	DE-A-26 22 053 (STANDARD PRESSED STEEL) * page 4, line 9 - line 33 * * page 5, line 7 - line 40 * * page 14, line 27 - page 15, line 39 * * page 18, line 10 - line 19; figures 1,2,3,5 *	1,5	
A	US-A-4 609 089 (KOBAYASHI) * column 1, line 42 - line 52; figures 1,3,4 *	1	
A	DE-A-31 28 558 (STAIGER MOHILO) * the whole document *	1,5	TECHNICAL FIELDS SEARCHED (Int.Cl.5) B25B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 July 1994	Matzdorf, U

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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